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(54) FLUID PRESSURE CYLINDER

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F15B 15/20 (2006.01)

(52) **U.S. Cl.**
CPC ***F15B 15/20*** (2013.01); ***F15B 15/14*** (2013.01)

(58) **Field of Classification Search**
CPC F15B 15/222; F15B 15/223; F15B 15/224
USPC 91/394, 409, 396
See application file for complete search history.

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(57) **ABSTRACT**

In a fluid pressure cylinder, a piston is displaced in an axial direction under the action of a pressure fluid. A circular protrusion, which projects toward the piston along an axial direction of the cylinder tube, is formed on an inner end surface of a collar member constituting part of the fluid pressure cylinder, a concavity, which can be fitted externally over the circular protrusion, is formed on the piston, and an annular groove is formed on an inner circumferential edge of an end plate. By the piston coming into contact with the end plate, a pressure receiving chamber is formed between the piston and the annular groove, together with an opening of a second port on an inner side of the cylinder tube being closed to a maximum of 90%.

2 Claims, 7 Drawing Sheets

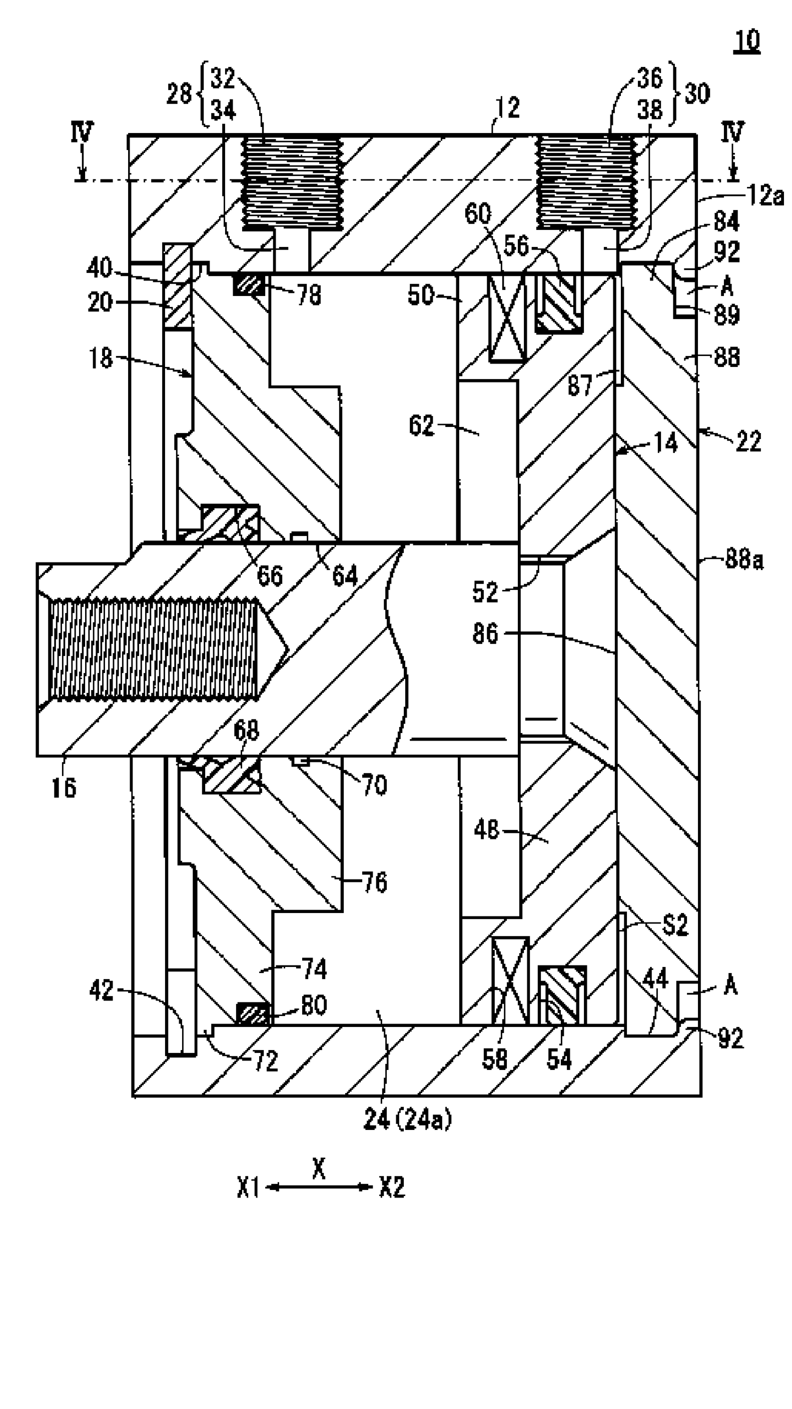


FIG. 1

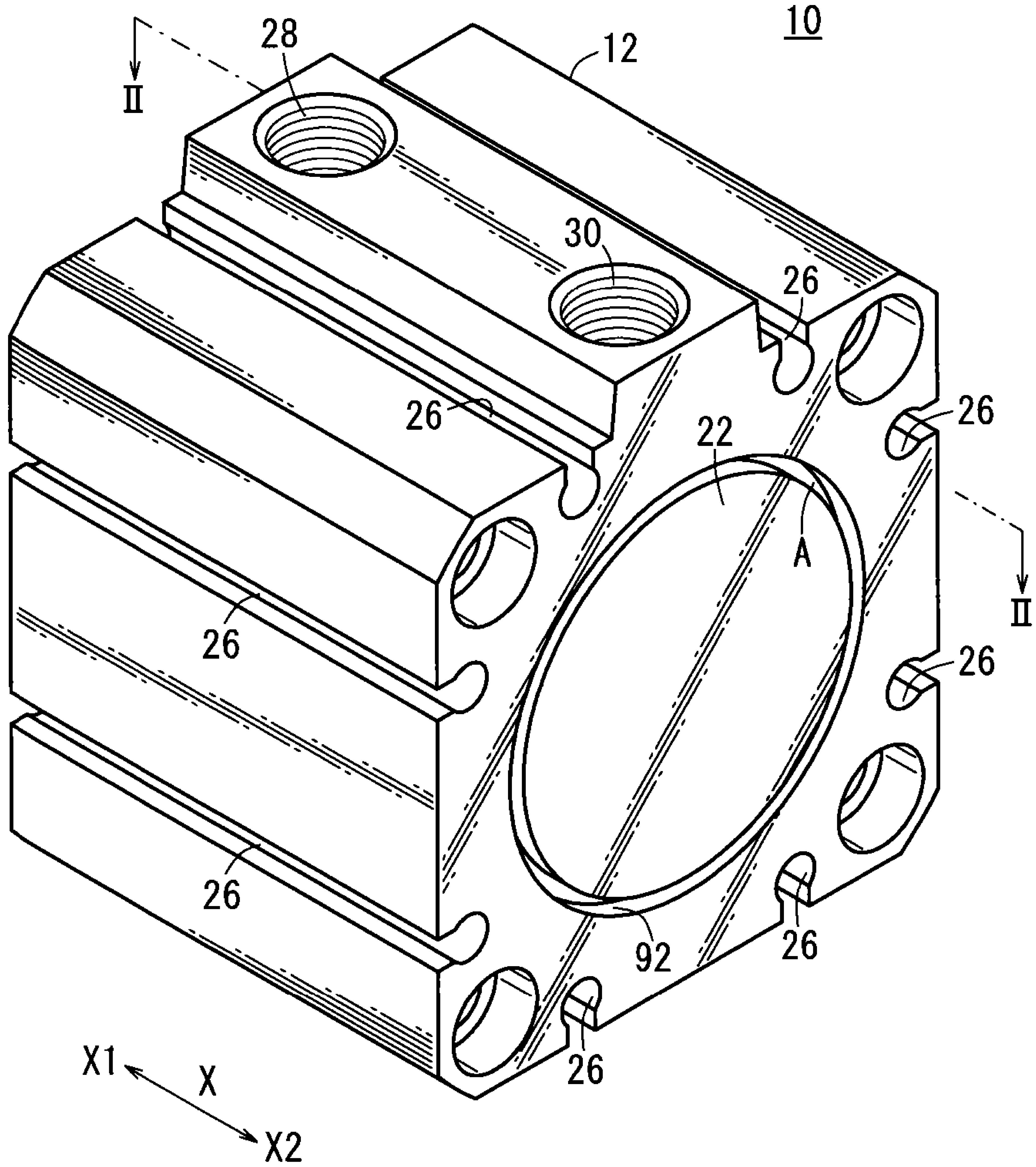
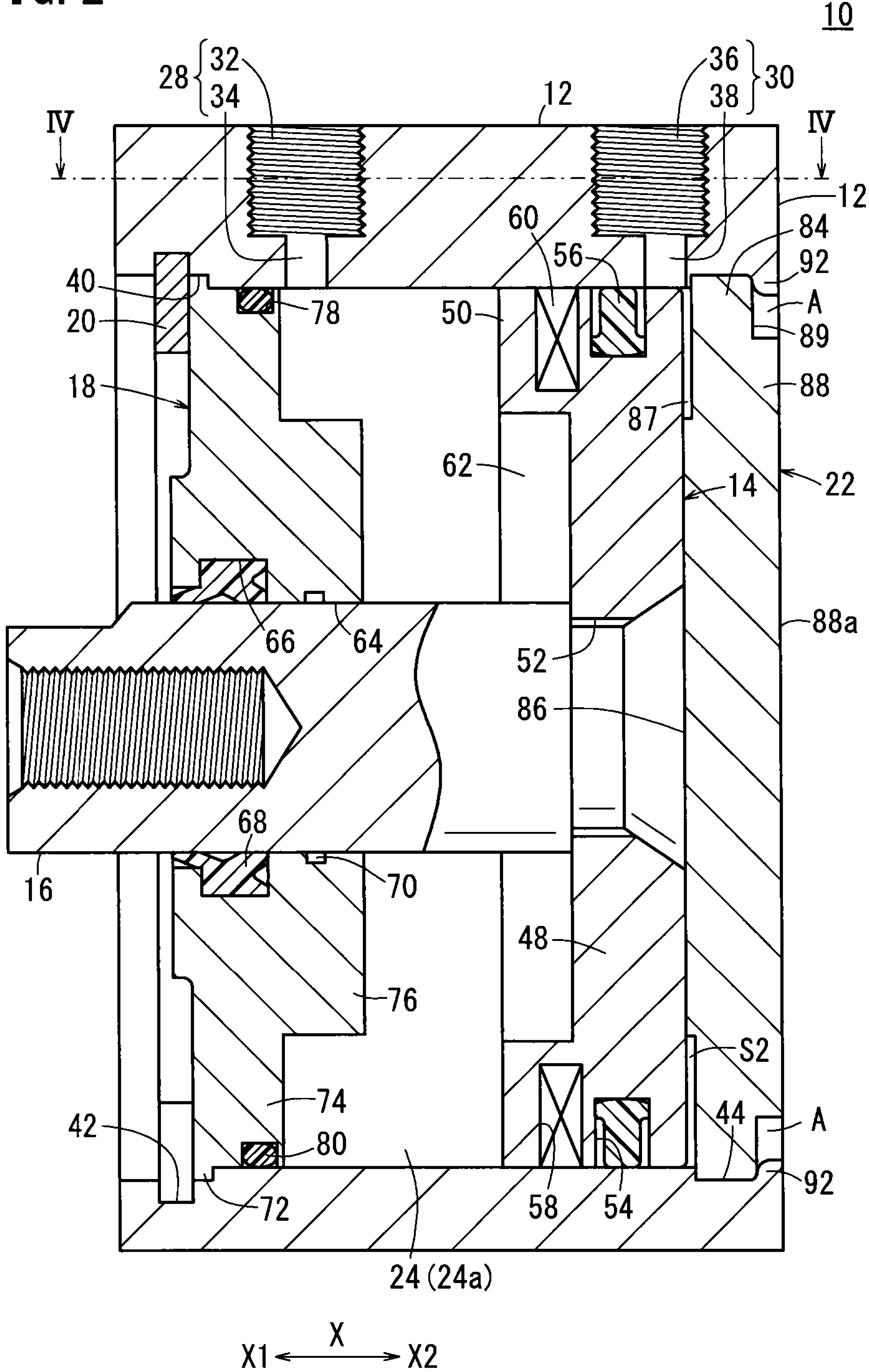


FIG. 2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88a
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16
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24 (24a)
X
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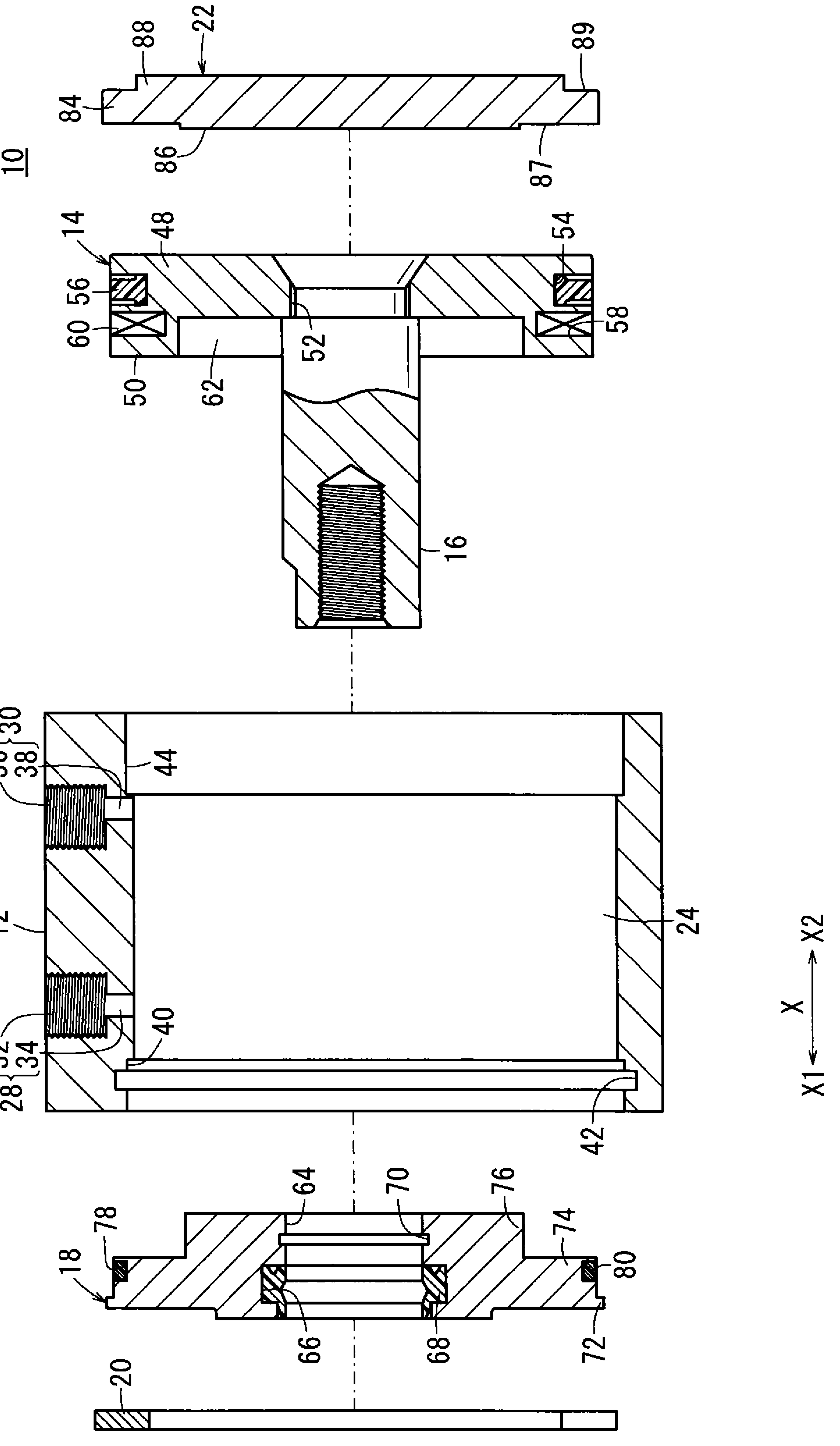
X2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X1
X2
18
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20

FIG. 3

FIG. 4

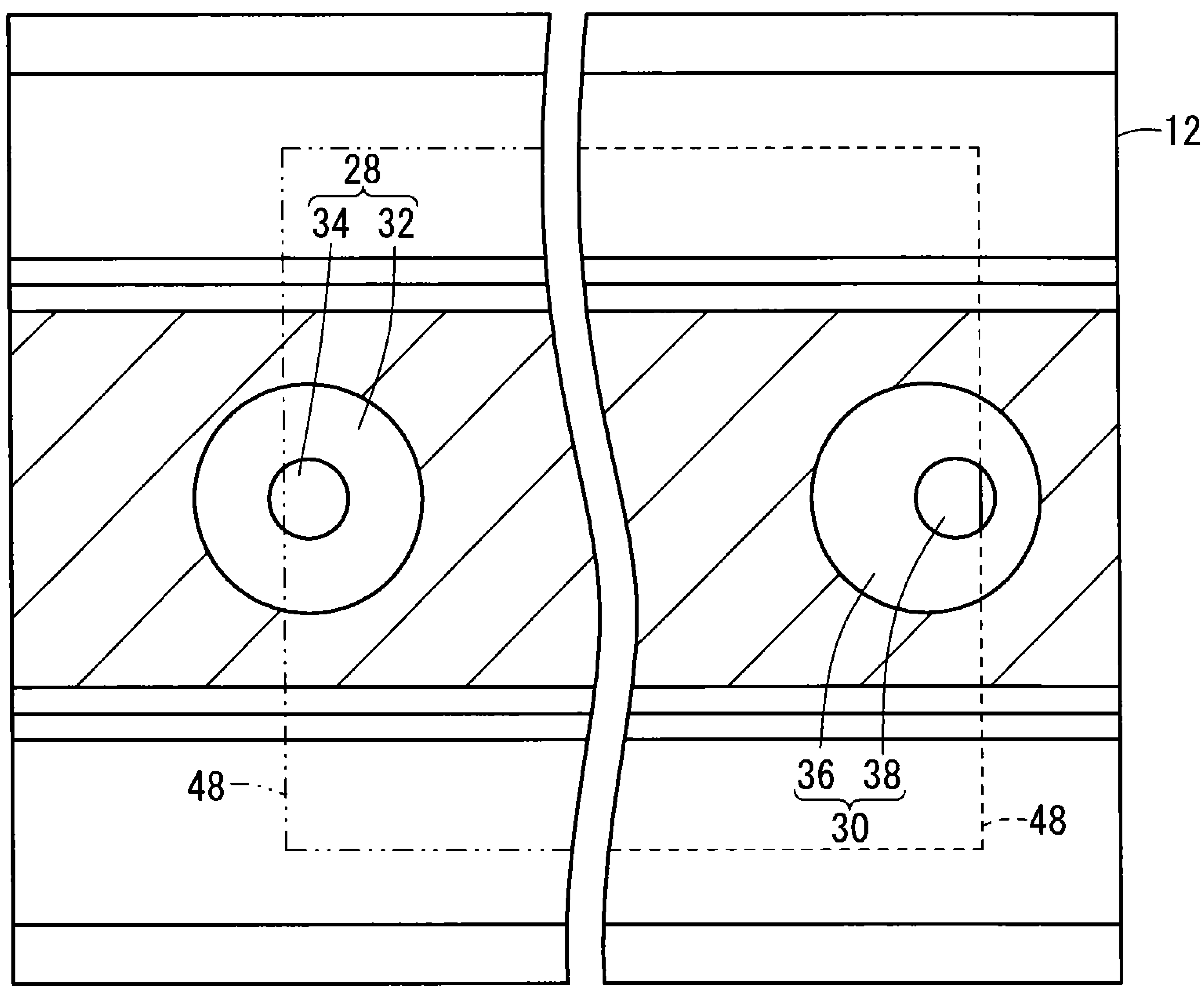
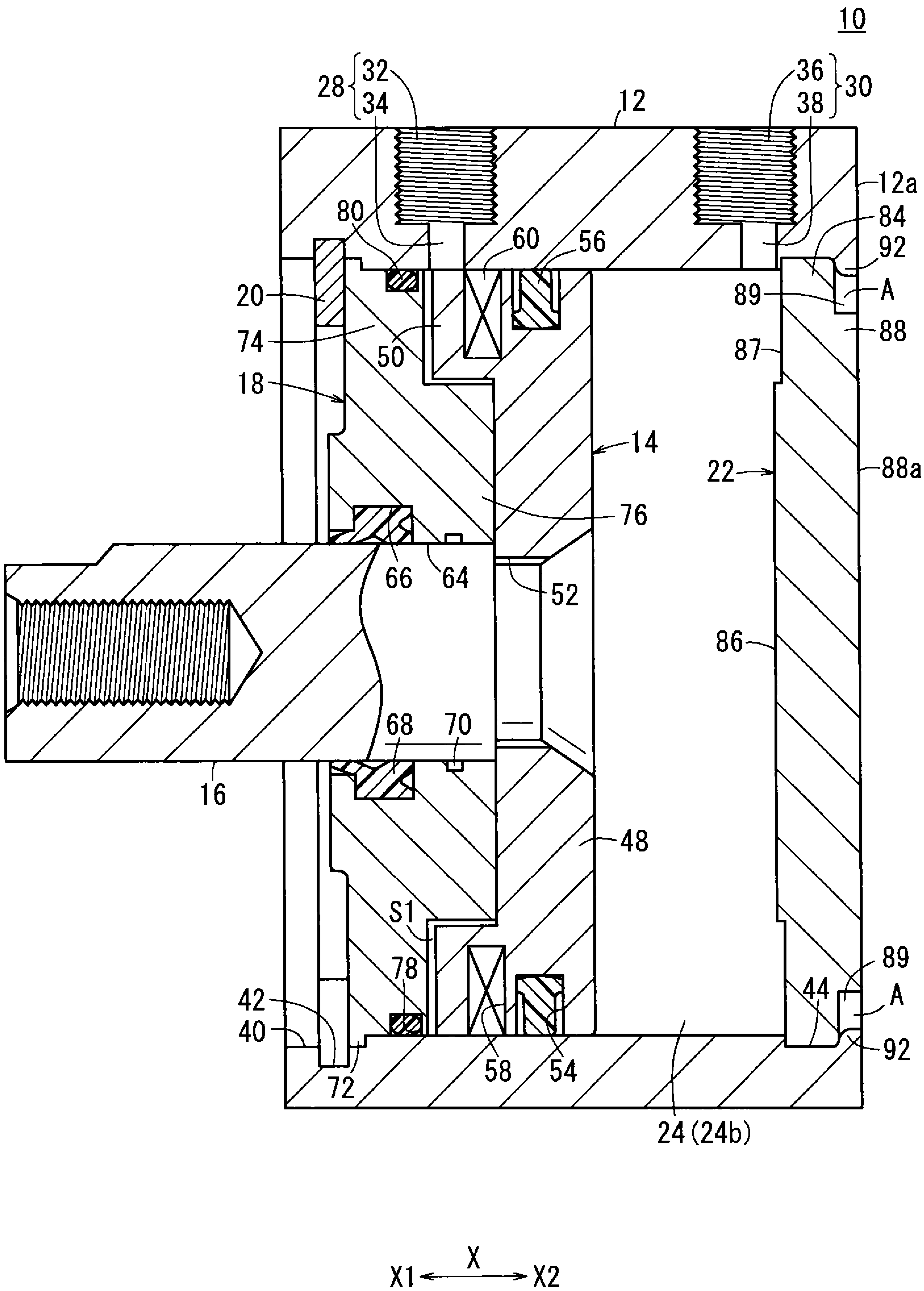


FIG. 5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92
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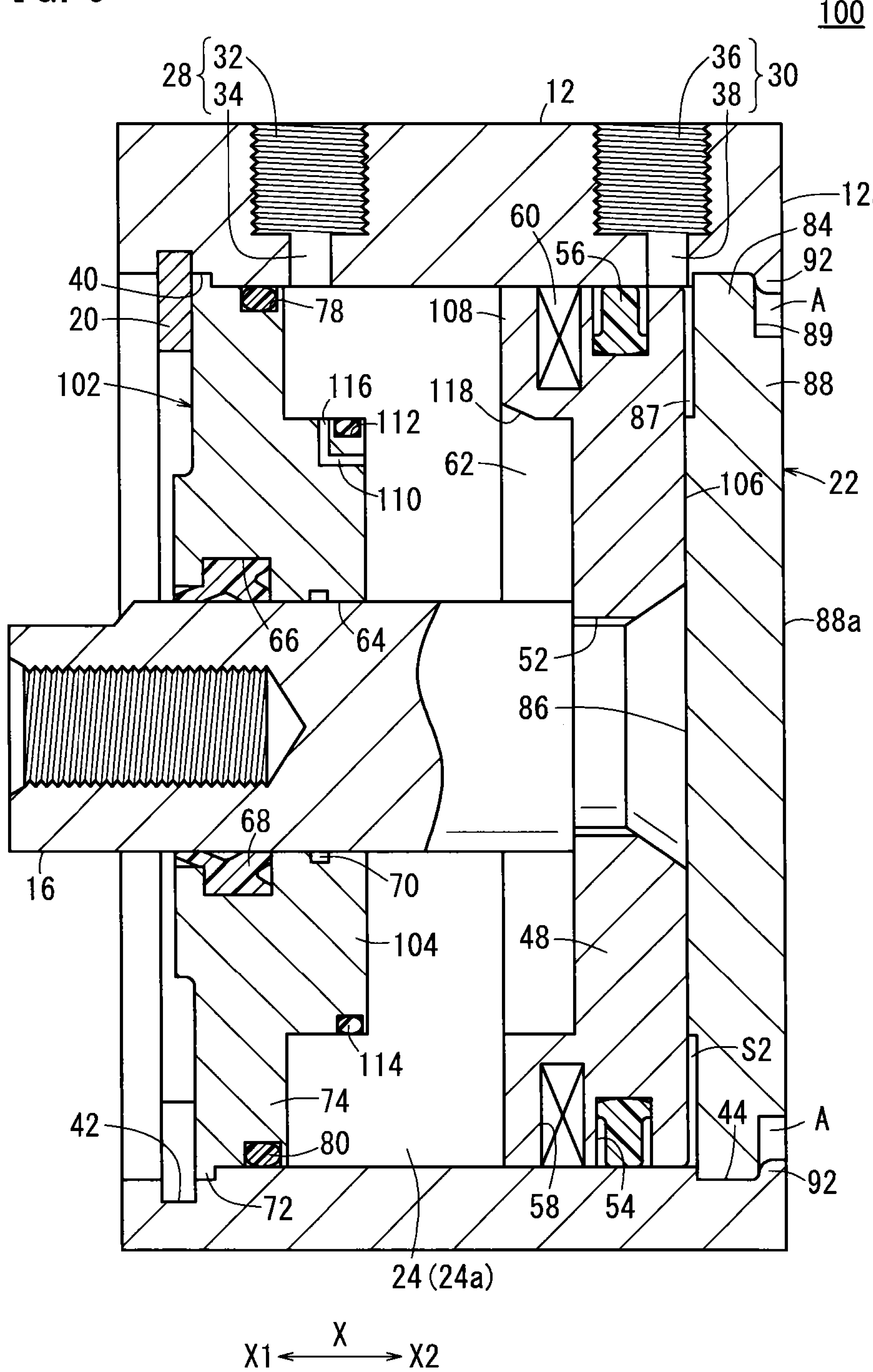
24 (24b)
X
X1
X2

FIG. 6



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S2
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92
24(24a)
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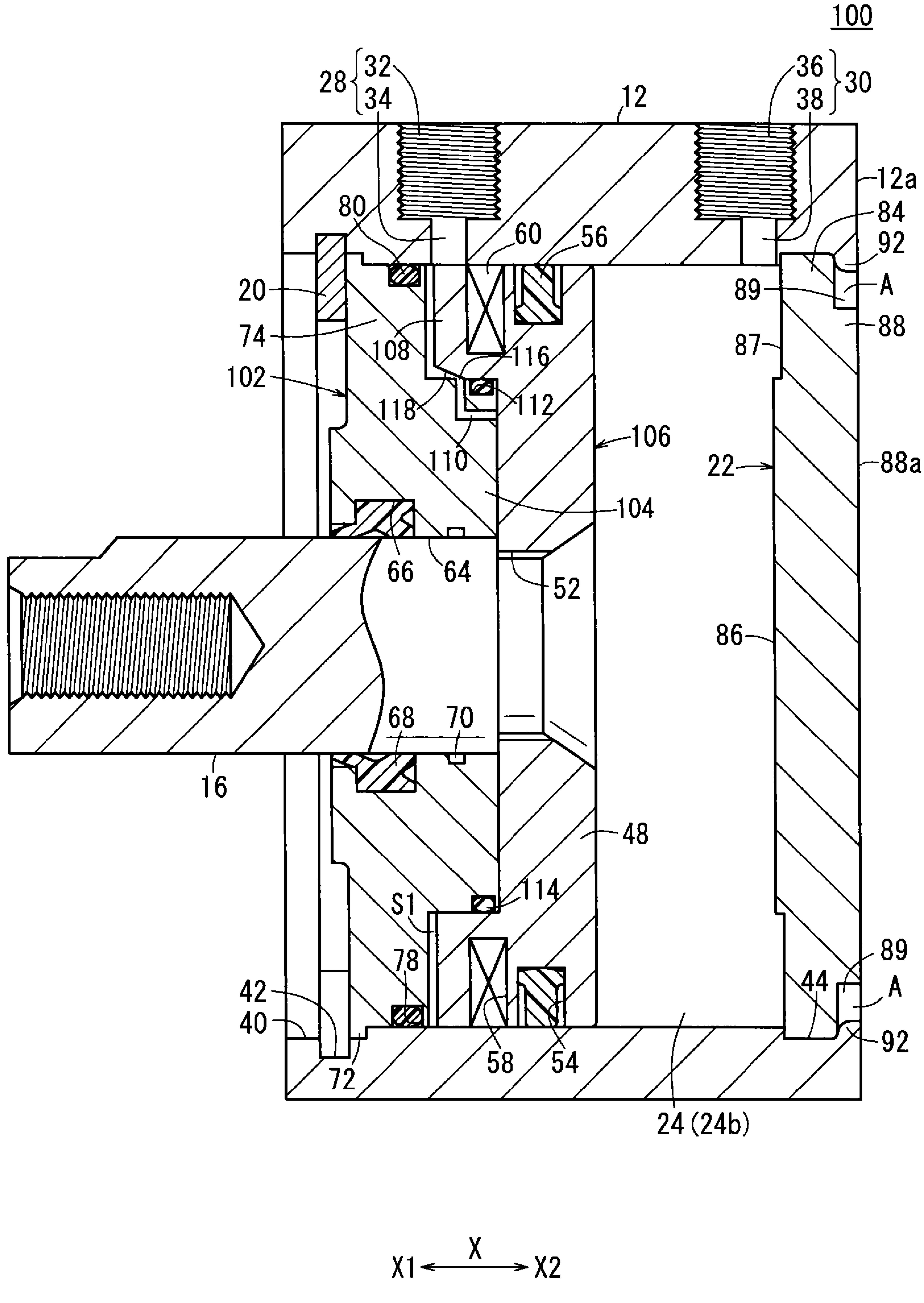
X1
X2

FIG. 7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FLUID PRESSURE CYLINDER

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2011-170888 filed on Aug. 4, 2011, of which the contents are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fluid pressure cylinder in which a piston is displaced in an axial direction under the action of a pressure fluid.

2. Description of the Related Art

Heretofore, fluid pressure cylinders have widely been used as workpiece transport means, or as operating means for positioning or operating various types of industrial machinery.

In general, in a fluid pressure cylinder, a piston disposed in the interior of a cylinder tube is displaced along an axial direction by a pressure fluid, which is supplied from a fluid supply port, and transporting and positioning, etc., of a workpiece is carried out through a piston rod, which is coupled to the piston. (See, Japanese Laid-Open Patent Publication No. 2005-240936.)

Concerning such cylinders, in recent years, techniques have been sought for reducing the size and scale of fluid pressure cylinders, and in particular, for shortening the length along the axial direction (i.e., the overall length of the fluid pressure cylinder) under a condition in which the stroke length of the piston (piston stroke) is maintained.

SUMMARY OF THE INVENTION

With the fluid pressure cylinder according to Japanese Laid-Open Patent Publication No. 2005-240936, at times when displacement of the piston is initiated and stopped, inertial forces tend to act on the workpiece. Consequently, as a result of such inertial forces, depending on the type of workpiece or the like, the position of the workpiece may become shifted with respect to the piston rod, resulting in reduced positioning accuracy.

For overcoming this kind of defect, a flow rate adjustment valve is used. More specifically, when initiation of displacement and stopping of the piston is carried out, the flow rate of the pressure fluid supplied to the interior of the cylinder tube and/or the flow rate of pressure fluid discharged from the cylinder tube is adjusted by the flow rate adjusting valve, whereby the inertial force that acts on the workpiece can be suppressed.

However, in addition to the increased cost required to incorporate such a flow rate adjustment valve therein, there is a concern that control of the flow rate adjustment valve, etc., may lead to complications.

The present invention has been conceived of to address the aforementioned problems. An object of the present invention is to provide a fluid pressure cylinder, which without using a flow rate adjustment valve or the like, is capable of suppressing inertial forces that act on the workpiece and thus can increase the accuracy with which a workpiece is positioned, while also enabling the overall length of the fluid pressure cylinder to be shortened under a condition in which the stroke length of the piston is maintained.

According to a first aspect of the present invention, a fluid pressure cylinder is provided characterized by a piston disposed displaceably in the interior of a cylinder tube, a piston rod connected to the piston, a first closure member for closing one end opening of the cylinder tube with the piston rod inserted therethrough, a second closure member inserted into another end opening of the cylinder tube for closing the other end opening, and a first port and a second port that open on an inner circumferential wall of the cylinder tube and through which a pressure fluid flows. A circular protrusion, which projects toward the piston along an axial direction of the cylinder tube, is formed on an inner end surface of the first closure member, a concavity, which can be fitted externally over the circular protrusion, is formed on the piston, and an annular groove is formed on an inner circumferential edge of the second closure member. By the piston coming into contact with the second closure member, a pressure receiving chamber is formed between the piston and the annular groove, together with an opening of the second port on an inner side of the cylinder tube being closed to a maximum of 90%.

According to the first aspect of the present invention, under a condition in which the piston contacts the second closure member, for example, if pressure fluid is supplied to the second port from a pressure fluid supply source, the pressure fluid flows into the pressure receiving chamber while the flow rate thereof is throttled appropriately at the opening on the second port on the inner side of the cylinder tube. Owing thereto, the flow rate at which pressure fluid flows into the pressure receiving chamber can suitably be reduced, and therefore the acceleration of the piston can be reduced as well. Thus, when displacement of the piston toward the side of the first closure member is initiated, inertial forces acting on the workpiece can be suppressed even though a flow rate adjustment valve is not used.

Further, when the piston is displaced toward the side of the first closure member under the action of the pressure fluid introduced from the second port, the circular protrusion of the first closure member enters into the concavity of the piston and the concavity is externally fitted over the circular protrusion. Owing thereto, the fluid (pressure fluid) introduced into the first port is throttled by a gap formed between the circular protrusion and the concavity, and therefore, the pressure of the fluid existing between the piston and the first closure member increases and the piston is decelerated. Thus, when movement of the piston is halted at the side of the first closure member, inertial forces acting on the workpiece can be suppressed even though a flow rate adjustment valve is not used.

Furthermore, when the piston is displaced toward the side of the second closure member under the action of the pressure fluid introduced from the first port, the opening of the second port on the inner side of the cylinder tube gradually becomes covered by the piston. Owing thereto, the fluid (pressure fluid) introduced into the second port is throttled by the opening, and therefore, the pressure of the fluid existing between the piston and the second closure member increases and the piston is gradually decelerated. Thus, when movement of the piston is halted at the side of the second closure member, inertial forces acting on the workpiece can be suppressed even though a flow rate adjustment valve is not used.

Further still, because the concavity formed on the piston is capable of being externally fitted over the circular protrusion formed on the first closure member, the total length of the fluid pressure cylinder can be shortened while the stroke length of the piston is maintained.

In a second aspect of the present invention, by the piston coming into contact with the circular protrusion, another pressure receiving chamber is formed between the piston and the first closure member, together with an opening of the first port on the inner side of the cylinder tube being closed to a maximum of 90%.

According to the second aspect of the present invention, when movement of the piston is initiated to the side of the second closure member, inertial forces acting on the workpiece can be suppressed even though a flow rate adjustment valve is not used. Further, when the piston is displaced toward the side of the first closure member by the pressure fluid flowing into the interior of the cylinder tube from the second port, because the opening of the first port gradually becomes covered by the piston, inertial forces acting on the workpiece can also be suppressed when movement of the piston is halted at the side of the first closure member.

In a third aspect of the present invention, in the fluid pressure cylinder noted above in relation to the second aspect, in a condition in which the piston contacts the second closure member, the opening of the second port on the inner side of the cylinder tube is 70% closed, and in a condition in which the piston contacts the circular protrusion, the opening of the first port on the inner side of the cylinder tube is 70% closed.

According to the third aspect of the present invention, in a state in which the piston contacts the second closure member, 30% of the opening of the second port on the inner side of the cylinder chamber communicates with the pressure receiving chamber, and in a state in which the piston contacts the circular protrusion, 30% of the opening of the first port on the inner side of the cylinder chamber communicates with the pressure receiving chamber. Therefore, the length in the axial direction of the fluid pressure cylinder can be reduced as much as possible, contributing to further miniaturization of the fluid pressure cylinder, together with preventing foreign matter such as grease or the like from blocking the communicating regions.

As described above, according to the present invention, because the pressure fluid, which is introduced to the second port from the fluid pressure supply source, flows into the pressure receiving chamber while the flow rate thereof is throttled appropriately at the opening of the second port on the inner side of the cylinder tube, when displacement of the piston toward the side of the first closure member is initiated, acceleration of the piston can be reduced. Further, when movement of the piston is halted at the side of the first closure member, because the fluid delivered into the first port is throttled by the gap between the circular protrusion and the concavity, the piston can be decelerated. Furthermore, when movement of the piston is halted at the side of the second closure member, because the opening of the second port on the inner side of the cylinder tube is gradually covered by the piston, the piston can gradually be decelerated. More specifically, even though a flow rate adjusting valve is not used, inertial forces acting on the workpiece can be suppressed, and thus positioning of the workpiece can be carried out with high accuracy. Moreover, because the concavity can be fitted externally over the circular protrusion, the total length of the fluid pressure cylinder can be shortened while the stroke length of the piston is maintained.

The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which a preferred embodiment of the present invention is shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exterior perspective view of a fluid pressure cylinder according to the present invention;

FIG. **2** is a cross sectional view taken along line II-II of FIG. **1**;

FIG. **3** is an exploded perspective view of the fluid pressure cylinder according to the present invention;

FIG. **4** is a cross sectional view taken along line IV-IV of FIG. **2**;

FIG. **5** is a cross sectional view showing a condition in which a piston is displaced to a rod end side;

FIG. **6** is a cross sectional view of a fluid pressure cylinder according to a modified example of the present invention; and

FIG. **7** is a cross sectional view showing a condition in which a piston is displaced to a rod end side, in the fluid pressure cylinder shown in FIG. **6**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of a fluid pressure cylinder according to the present invention will be described in detail below with reference to the accompanying drawings.

As shown in FIGS. **1** and **2**, a fluid pressure cylinder **10** is equipped with a tubular shaped cylinder tube **12** substantially in the shape of a rectangular parallelepiped, a piston **14** slidably disposed in the interior of the cylinder tube **12**, a piston rod **16** connected to the piston **14**, a collar member (first closure member) **18** that closes a front end opening (an opening in the direction of the arrow X**1**) of the cylinder tube **12**, a retaining ring **20** for preventing movement of the collar member **18** in the direction of the arrow X**1**, and an end plate (second closure member) **22** that closes a rear end opening (an opening in the direction of the arrow X**2**) of the cylinder tube **12**.

A cylinder chamber **24** is formed by the inner end surface of the collar member **18**, the inner end surface of the end plate **22**, and the inner circumferential surface of the cylinder tube **12** (see FIG. **2**). The structure of the collar member **18** will be explained later.

The cylinder tube **12** is constituted from a metal material such as an aluminum alloy or the like. On the outer circumferential surface thereof, plural sensor grooves **26** (eight as shown in FIG. **1**) extend along the axial direction (the direction of the arrow X) of the cylinder tube **12**, in which non-illustrated sensors (magnetic sensors) capable of detecting the position of the piston may be installed.

As shown in FIGS. **2** and **3**, a first port **28**, which is positioned somewhat more in the direction of the arrow X**1** from the center of the cylinder tube **12**, and a second port **30**, which is positioned in the vicinity of the end in the direction of the arrow X**2**, are formed in the cylinder tube **12**.

The first port **28** includes a first connection hole **32** with threaded grooves engraved therein, and a first communication hole **34** that communicates with the first connection hole **32** and which opens on the inner circumferential surface of the cylinder tube **12**. The central axes of the first connection hole **32** and the first communication hole **34** are substantially coaxial.

The second port **30** includes a second connection hole **36** with threaded grooves engraved therein, and a second communication hole **38** that communicates with the second connection hole **36** and which opens on the inner circumferential surface of the cylinder tube **12**. The central axis of the second communication hole **38** is offset in the direction of the arrow X**2** from the central axis of the second connection hole **36**.

The size of the second connection hole **36** is set substantially the same as the size of the first connection hole **32**, and the size of the second communication hole **38** is set substantially the same as the size of the first communication hole **34**.

In this case, a non-illustrated external device is connected to the first connection hole **32** and the second connection hole **36** for supplying a pressure fluid, for example, pressurized air, thereto.

On the inner circumferential surface of the cylinder tube **12**, on the end in the direction of the arrow X**1**, a first groove **40** for installation therein of the collar member **18**, and a second groove **42** for installation therein of the retaining ring **20** are formed respectively in annular shapes. The retaining ring is a C-shaped member which is used to prevent the collar member **18** from moving in the axial direction.

Further, on the inner circumferential surface of the cylinder tube **12**, on the end in the direction of the arrow X**2**, a third groove **44** for installation therein of the end plate **22** is formed. The groove depth of the first and third grooves **40**, **44** is set substantially the same for both grooves.

The piston **14** is provided in the interior of the cylinder chamber **24** so as to be displaceable along the directions of the arrows X**1** and X**2**. Consequently, the cylinder chamber **24** is divided into a first cylinder chamber **24***a* that communicates with the first port **28**, and a second cylinder chamber **24***b* that communicates with the second port **30** (see FIG. **5**).

Further, the piston **14** includes a piston main body **48** formed in a disk shape, and an annular protrusion **50** that projects toward the side of the collar member **18** from one end surface (back surface) of the piston main body **48**.

The outer circumferential edge of the piston main body **48** is chamfered, and together therewith, in the center of the piston main body **48**, a through hole **52** is formed that penetrates in the axial direction.

One end of the piston rod **16** is inserted through the through hole **52**, and the piston main body **48** and the piston rod **16** are joined together integrally. The other end of the piston rod **16** penetrates through the collar member **18** and extends outward from the cylinder tube **12**. A piston packing **56**, which is made of resin or the like, is mounted in an annular groove **54** provided in the piston main body **48**, and a magnetic body **60** is mounted in an annular groove **58** provided on the annular protrusion **50**. The magnetic body **60** is disposed at a position so as not to block the first communication hole **34**. By formation of the annular protrusion **50**, a concavity **62** is formed in the one end side of the piston main body **48**.

The collar member **18**, for example, is constructed from a metal material such as an aluminum alloy or the like, and has an insertion hole **64** formed therein through which the piston rod **16** penetrates along the axial center.

The insertion hole **64** expands in diameter on the side of the retaining ring **20**, and an annular groove **66** is formed therein. A rod packing **68** made of resin or the like is mounted in the annular groove **66**. On the other hand, on the end plate **22** side of the insertion hole **64**, an oil pocket **70** is formed therein for storing a lubricating oil in the collar member **18**.

The collar member **18**, which is constructed in the foregoing manner, also includes a large diameter portion **72** mounted in the first groove **40** of the cylinder tube **12**, an intermediate diameter portion **74** in contact with the inner circumferential surface of the cylinder tube **12**, and a small diameter portion (circular protrusion) **76** joined continuously with the intermediate diameter portion **74** and which can be fitted into the concavity **62** of the piston **14**.

In this case, the diameter of the small diameter portion **76** is slightly smaller than the diameter of the concavity **62**, and the axial length of the small diameter portion **76** is longer than the depth of the concavity **62**. An O-ring **80** made of resin or the like is mounted in an annular groove **78** provided in the collar member **18**.

The end plate **22** is constructed, for example, from a metal material such as an aluminum alloy or the like, and includes an end plate main body **84** mounted in the aforementioned third groove **44**, a first projection **86** that projects toward the side of the collar member **18** from one end surface of the end plate main body **84**, and a second projection **88** that projects outwardly from another end surface of the end plate main body **84**. The end plate main body **84**, the first projection **86**, and the second projection **88** are formed integrally and make up a disk shape as a whole.

Further, in a condition in which the end plate **22** is inserted and arranged in the cylinder tube **12** via the rear end opening of the cylinder tube **12**, the one end of the cylinder tube **12** is caulked or crimped, thereby fixing the end plate **22** in the cylinder tube **12**. At this time, an overhanging part **92**, which projects in a radial inward direction from the third groove **44**, is formed in an annular shape. In addition, as can be appreciated from FIG. **5**, a gap A is formed between the outer circumferential surface of the second projection **88** and the overhanging part **92**.

By formation of the first projection **86**, an annular groove **87** is formed on one end surface of the end plate main body **84**, and by formation of the second projection **88**, another annular groove **89** is formed on the other end surface of the end plate main body **84**.

The outer diameters of the first and second projections **86**, **88** can be set arbitrarily. In the present embodiment, for example, the outer diameter of the first projection **86** is set substantially equivalent to the outer diameter of the small diameter portion **76**, and the outer diameter of the second projection **88** is set smaller than the inner diameter of the cylinder tube **12** and larger than the outer diameter of the first projection **86**.

The amount by which the first projection **86** projects in the axial direction is set to be smaller than the hole diameter of the second communication hole **38**. More specifically, the amount by which the first projection **86** projects is set, for example, to a size on the order of about ⅓ the inner diameter of the second communication hole **38**. For example, the amount by which the first projection **86** projects preferably is set to substantially the same size as the difference between the amount by which the small diameter portion **76** projects and the amount by which the annular projection **50** projects. Further, although the amount by which the second projection **88** projects can be set arbitrarily, preferably, the amount of projection is of an order such that, upon completion of assembly, the second projection **88** lies substantially flush with an end surface **12***a* of the cylinder tube **12**. More specifically, the amount by which the second projection **88** projects may be set such that, upon completion of assembly, an outer end surface **88***a* of the second projection **88** is positioned slightly inward (toward the side of the piston **14**) from the end surface **12***a* of the cylinder tube **12**.

With the fluid pressure cylinder **10** constructed in the foregoing manner, in a condition in which the piston **14** contacts the inner end surface of the small diameter portion **76** of the collar member **18** (i.e., in the state shown in FIG. **5**, hereinafter referred to as a "first state"), a space (pressure receiving chamber) S**1** is formed as a region surrounded by the inner end surface of the intermediate diameter portion **74**, the outer circumferential surface of the small diameter portion **76**, the rear surface of the piston main body **48**, the inner circumferential surface of the annular protrusion **50**, the inner end surface of the annular protrusion **50**, and the inner circumferential surface of the cylinder tube **12**.

In addition, as shown in FIG. **4**, the first communication hole **34** faces the outer circumferential surface of the piston

14, and is blocked up to a maximum of 90% by the outer circumferential surface of the piston 14. Owing thereto, the flow amount of pressure fluid flowing into the space S1 (first cylinder chamber 24a), and the amount of pressure fluid that flows out from the first cylinder chamber 24a can be throttled or constricted to a suitable degree by the open portion of the first communication hole 34.

Preferably, the first communication hole 34 is blocked 70% by the outer circumferential surface of the piston 14. Consequently, in the first state, because the first communication hole 34 communicates through 30% of the opening to the space S1, the length in the axial direction of the fluid pressure cylinder 10 can be reduced, thereby minimizing the scale of the fluid pressure cylinder 10 as much as possible, while still preventing foreign matter such as grease or the like from blocking the portion of the opening of the first communication hole 34 that remains in communication with the space S1.

On the other hand, in a condition in which the piston 14 contacts the inner end surface of the first projection 86 (i.e., the state shown in FIG. 2, hereinafter referred to as a "second state"), a space (pressure receiving chamber) S2 is formed by the upper end surface of the piston 14, the outer circumferential surface of the first projection 86, the inner end surface of the end plate main body 84, and the inner circumferential surface of the cylinder tube 12. The volume (cubic capacity) of the space S2 is set to be larger than the volume (cubic capacity) of the space S1.

In addition, the second communication hole 38 faces the outer circumferential surface of the piston 14, and is blocked up to a maximum of 90% by the outer circumferential surface of the piston 14. Owing thereto, the flow amount of pressure fluid flowing into the space S2 (second cylinder chamber 24b), and the amount of pressure fluid that flows out from the second cylinder chamber 24b can be throttled or constricted to a suitable degree by the open portion of the second communication hole 38.

Preferably, the second communication hole 38 is blocked 70% by the outer circumferential surface of the piston 14. Consequently, in the second state, because the second communication hole 38 communicates through 30% of the opening to the space S2, the length in the axial direction of the fluid pressure cylinder 10 can be reduced, thereby minimizing the scale of the fluid pressure cylinder 10 as much as possible, while still preventing foreign matter such as grease or the like from blocking the portion of the opening of the second communication hole 38 that remains in communication with the space S2.

As described above, with the present embodiment, between the overhanging part 92 and the outer circumferential surface of the second projection 88, a gap A is formed, and the overhanging part 92 is formed by caulking one end of the cylinder tube 12. Therefore, even without providing a seal member, a desired sealing capability can reliably be assured. Thus, since the number of parts can be reduced, manufacturing costs for the fluid pressure cylinder 10 can be reduced as well.

Further, by installing a non-illustrated ring member in the gap A, positioning of the fluid pressure cylinder 10 can easily be performed.

Furthermore, because the outer end surface 88a of the second projection 88 is shifted slightly more in the direction of the arrow X1 (toward the side of the piston 14) than the end surface 12a of the cylinder tube 12, compared to a case of caulking the end plate 22 to the cylinder tube 12 such that the outer end surface 88a of the second projection 88 is positioned more in the direction of the arrow X2 than the end surface 12a of the cylinder tube 12, the total length of the fluid pressure cylinder 10 in the direction of the arrow X can be shortened.

Next an explanation will be made concerning operations and effects of the fluid pressure cylinder 10 according to the present invention.

In the second state, in a condition in which the first port 28 is open to atmosphere, when a pressure fluid (e.g., pressurized air) is supplied to the second connection hole 36 from a non-illustrated pressure fluid supply source, the pressure fluid flows into the space S2 (second cylinder chamber 24b) at the opening of the second communication hole 38 on the inner side of the cylinder tube 12 while the flow rate is throttled appropriately (e.g., on the order of 30%).

In addition, under an action of the pressure fluid directed into the space S2, the piston 14 is displaced in the direction of the arrow X1 (toward the front end side). At this time, acceleration of the piston 14 is proportional to the rate at which the pressure fluid flows into the space S2, and therefore, when supply of the pressure fluid is initiated, acceleration of the piston 14 is suitably small. In other words, abrupt flying off of the piston 14 toward the one end side is suppressed.

As the piston 14 moves in the direction of the arrow X1, the area ratio of the opening of the second communication hole 38 that communicates with the second cylinder chamber 24b gradually becomes larger, or stated otherwise, the communicating area of the opening of the second communication hole 38 with respect to the second cylinder chamber 24b gradually increases. Therefore, the rate at which the pressure fluid flows into the second cylinder chamber 24b (inflow rate per unit time) gradually increases, and as a result, the acceleration of the piston 14 rises.

Subsequently, the entire opening of the second communication hole 38 becomes exposed to the second cylinder chamber 24b, and the piston 14 is displaced in the direction of the arrow X1 at a constant velocity.

Thereafter, when the concavity 62 of the piston 14 is fitted over the small diameter portion 76 of the collar member 18, because the flow rate of the fluid directed into the first communication hole 34 is limited (made small) due to the gap created between the annular protrusion 50 and the small diameter portion 76, the fluid pressure inside the concavity 62 progressively increases. Consequently, since the displacement operation of the piston 14 is constrained, the piston 14 gradually decelerates. Stated otherwise, the fluid inside the concavity 62 acts to carry out a cushioning effect (air cushion effect) on the piston 14.

Next, as the piston 14 is further displaced in the direction of the arrow X1 while decelerating, the opening of the first communication hole 34 on the inner side of the cylinder tube 12 gradually becomes covered by the annular protrusion 50. As a result, since the fluid inside the first cylinder chamber 24a that is guided into the first communication hole 34 is throttled or constricted by the opening of the first communication hole 34, the pressure of the fluid inside the first cylinder chamber 24a becomes higher, and the piston 14 is further decelerated.

In addition, when the wall that forms the concavity 62 of the piston main body 48 contacts the inner end surface of the small diameter portion 76, the piston 14 is stopped, and the first state is brought about (see FIG. 5). At this time, a space S1 is formed between the piston 14 and the collar member 18, together with a portion (e.g., 70%) of the opening of the first communication hole 34 being covered by the annular protrusion 50.

On the other hand, when supply of the pressure fluid is switched from the second port 30 to the first port 28 under a switching action of a non-illustrated switching valve, pressure fluid from the aforementioned pressure fluid supply source is supplied to the first connection hole **32**, whereupon the pressure fluid flows into the space S**1** (first cylinder chamber **24***a*) while the flow rate of the pressure fluid is throttled to a suitable degree (for example, 30%) at the opening of the first communication hole **34** on the inner side of the cylinder tube **12**.

In addition, under an action of the pressure fluid directed into the space S**1**, the piston **14** is displaced in the direction of the arrow X**2** (toward the rear end side). At this time, acceleration of the piston **14** is proportional to the rate at which the pressure fluid flows into the space S**1**, and therefore, when displacement of the piston **14** is initiated, acceleration of the piston **14** is suitably small.

In this case, because the volume of the space S**1** is set to be smaller than the volume of the space S**2**, the acceleration of the piston **14** at the time that displacement toward the side of the end plate **22** is initiated becomes greater than the acceleration of the piston **14** at the time that displacement toward the side of the collar member **18** is initiated.

As the piston **14** continues to move in the direction of the arrow X**2**, the area ratio of the opening of the first communication hole **34** that communicates with the first cylinder chamber **24***a* gradually becomes larger, or stated otherwise, the communicating area of the opening of the first communication hole **34** with respect to the first cylinder chamber **24***a* gradually increases. Therefore, the rate at which the pressure fluid flows into the first cylinder chamber **24***a* (inflow rate per unit time) gradually increases, and as a result, the piston **14** is gradually accelerated.

Then, the entire opening of the first communication hole **34** becomes exposed to the first cylinder chamber **24***a*, and the piston **14** is displaced in the direction of the arrow X**2** at a constant velocity.

Thereafter, by the piston **14** being displaced in the direction of the arrow X**2**, the opening of the second communication hole **38** on the inner side of the cylinder tube **12** becomes gradually covered by the piston **14**. As a result, since the fluid inside the second cylinder chamber **24***b* that is guided into the second communication hole **38** is throttled or constricted by the opening of the second communication hole **38**, the pressure of the fluid inside the second cylinder chamber **24***b* becomes higher, and the piston **14** is decelerated.

In addition, when the upper surface of the piston main body **48** contacts the inner end surface of the first projection **86**, the piston **14** is stopped and the second state is restored. In this manner, the piston **14** accommodated in the cylinder chamber **24** can be moved reciprocally along the axial direction.

As discussed above, using the fluid pressure cylinder **10** according to the present embodiment, at times when movement of the piston **14** is initiated (at initiation of workpiece displacement) and when the movement of the piston **14** is stopped (when the workpiece is stopped), inertial forces acting on the workpiece can suitably be suppressed. Consequently, positioning accuracy of the workpiece can be improved, even though a flow rate adjustment valve or the like, which is capable of adjusting the flow rate of the pressure fluid flowing into the cylinder chamber **24**, is not used.

With the fluid pressure cylinder **10** according to the present invention, upon displacement of the piston **14** in the direction of the arrow X**1**, because the concavity **62** can be externally fitted over the small diameter portion **76**, compared to a case in which the concavity **62** and the small diameter portion **76** are not provided, the total length of the fluid pressure cylinder **10** can be shortened while the stroke length of the piston **14** is maintained.

MODIFIED EXAMPLE

Next, with reference to FIGS. **6** and **7**, a description shall be given of a fluid pressure cylinder **100** according to a modified example. Constituent elements of the modified example, which are the same as those of the above-discussed embodiment, are denoted by the same reference characters and duplicate descriptions of such features are omitted.

As shown in FIG. **6**, the fluid pressure cylinder **100** according to the present modified example differs in relation to the structure of a small diameter portion **104** constituting a collar member **102**, and the structure of the annular protrusion **108** of a piston **106**. More specifically, a bypass hole **110** is formed in an end surface (i.e., a surface that confronts the piston main body **48**) of the small diameter portion **104**, and an O-ring **114** made of resin or the like is installed in an annular groove **112** formed on the outer circumferential surface of the small diameter portion **104**. The bypass hole **110** opens at a region on the outer circumferential surface of the small diameter portion **104**, which is more proximate to the side of the intermediate diameter portion **74** than the annular groove **112**.

Further, on the inner circumferential surface of an annular protrusion **108** at a region thereof confronting an opening **116** of the bypass hole **110**, a tapered portion **118** is formed, which widens diametrically outward in the direction of the arrow X**1**.

With the fluid pressure cylinder **100** according to the modified example, when a pressure fluid is supplied to the second connection hole **36** to thereby cause displacement of the piston **106** in the direction of the arrow X**1**, the concavity **62** of the piston **106** is fitted over the small diameter portion **104** of the collar member **102**. At this time, at a stage when such fitting begins, by means of a gap formed between the annular protrusion **108** and the small diameter portion **104** as well as the bypass hole **110**, the flow rate of the fluid that is directed into the first communication hole **34** is restricted and the piston **106** is gradually decelerated.

In addition, as shown in FIG. **7**, upon further displacement of the piston **106** in the direction of the arrow X**1**, because the O-ring **114** comes into sliding contact with the inner circumferential surface of the annular protrusion **108** and flow of fluid through the aforementioned gap is blocked, or stated otherwise, because the fluid inside the concavity **62** of the piston **106** can flow only through the bypass hole **110**, the flow rate of the fluid directed into the first communication hole **34** is further restricted. Consequently, the piston **106** is decelerated even more. In other words, the bypass hole **110** acts to carry out a cushioning effect (air cushion effect) on the piston **106**. Moreover, at this time, the fluid introduced from the opening **116** is guided suitably by the tapered portion **118** into the gap between the annular protrusion **108** and the intermediate diameter portion **74**.

The present invention is not limited to the aforementioned embodiments, and it is a matter of course that various additional or modified structures could be adopted therein without deviating from the essence and gist of the present invention.

What is claimed is:

1. A fluid pressure cylinder, comprising:
- a piston disposed displaceably in the interior of a cylinder tube;
- a piston rod connected to the piston;
- a first closure member for closing one end opening of the cylinder tube with the piston rod inserted therethrough;
- a second closure member inserted into another end opening of the cylinder tube for closing the other end opening; and

a first port and a second port that open to the interior of the cylinder tube on an inner circumferential wall of the cylinder tube and through which a pressure fluid flows to move the piston along an axial direction of the cylinder tube,

wherein a circular protrusion, which projects toward the piston along the axial direction of the cylinder tube, is formed on an inner end surface of the first closure member, wherein one of the first port and the second port is provided on the inner circumferential wall of the cylinder tube at a position along an axial direction which at least partly overlaps the position along an axial direction of the projection of the circular protrusion,

a concavity, which can be fitted externally over the circular protrusion, is formed on the piston,

an annular groove is formed on an inner circumferential edge of the second closure member, wherein the other of the first port and the second port is provided on the inner circumferential wall of the cylinder tube at a position along an axial direction which at least partly overlaps the position along an axial direction of the annular groove, wherein

by the piston coming into contact with the second closure member, a pressure receiving chamber is formed between the piston and the annular groove, together with an opening of the second port on an inner side of the cylinder tube being closed by the piston to a maximum of 90%, and

by the piston coming into contact with the circular protrusion, another pressure receiving chamber is formed between the piston and the first closure member, together with an opening of the first port on the inner side of the cylinder tube being closed by the piston to a maximum of 90%.

2. The fluid pressure cylinder according to claim **1**, wherein in a condition in which the piston contacts the second closure member, the opening of the second port on the inner side of the cylinder tube is 70% closed, and in a condition in which the piston contacts the circular protrusion, the opening of the first port on the inner side of the cylinder tube is 70% closed.

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